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Request for grant of a patent

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The Patent Office

Cardiff Road
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1. Your reference
9889.

2. Patent application number *(The Patent Office will fill in this part)*
0217288.0 25 JUL 2002

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

(1) BP EXPLORATION OPERATING COMPANY LIMITED
BRITANNIC HOUSE
1 FINSBURY CIRCUS
LONDON, EC2M 7BA, UNITED KINGDOM 6225916002

Patents ADP number *(if you know it)*

AND

If the applicant is a corporate body, give the country/state of its incorporation

(2) XL TECHNOLOGY LIMITED
GIBB HOUSE
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4. Title of the invention
METHOD

5. Name of your agent *(if you have one)*
COLLINS, Frances Mary

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

BP INTERNATIONAL LIMITED
PATENTS & AGREEMENTS
CHERTSEY ROAD
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UNITED KINGDOM

Patents ADP number *(if you know it)* 7093438001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
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Claim*(s)*	–
Abstract	–
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Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	--

11. I/We request the grant of a patent on the basis of this application.

Signature F. M. Collins Date 25th July 2002

COLLINS, Frances Mary

12. Name and daytime telephone number of person to contact in the United Kingdom 01932 763206

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METHOD

The present invention relates to a method of drilling a borehole from a selected location in an existing wellbore penetrating a subterranean hydrocarbon-bearing formation using a remotely controlled electrically operated drilling device wherein the drilling device is introduced into the existing wellbore through a hydrocarbon fluid production conduit and produced fluid, for example produced liquid hydrocarbon and/or produced water is pumped over the cutting surfaces of the drilling device using a remotely controlled electrically operated pumping means to cool the cutting surfaces and to transport drill cuttings away from the drilling device.

In conventional methods of wellbore drilling a drill string including a drill bit at its lower end is rotated in the wellbore while drilling fluid is pumped through a longitudinal passage in the drill string, which drilling fluid returns to surface via the annular space between the drill string and the wellbore wall. When drilling through an earth layer not containing a fluid, the weight and the pumping rate of the drilling fluid are selected so that the pressure at the wellbore wall is kept between a lower level at which the wellbore becomes unstable and an upper level at which the wellbore wall is fractured. When the wellbore is drilled through a hydrocarbon fluid containing zone the drilling fluid pressure should moreover be above the pressure at which hydrocarbon fluid starts flowing into the wellbore, and below the pressure at which undesired invasion of drilling fluid into the formation occurs. These requirements impose certain restrictions to the drilling process, and particularly to the length of the wellbore intervals at which casing is to be installed in the wellbore. For example, if the drilling fluid pressure at the wellbore bottom is just below the upper limit at which undesired drilling

fluid invasion into the formation occurs, the drilling fluid pressure at the top of the open-hole wellbore interval can be close to the lower limit at which hydrocarbon fluid influx occurs. The maximum allowable length of the open-hole interval depends on the specific weight of the drilling fluid, the hydrocarbon fluid pressure in the formation, and the height of the drilling fluid column.

Furthermore, it has been practised to drill through a hydrocarbon fluid bearing zone at wellbore pressures below the formation fluid pressure, a methodology commonly referred to as under-balanced drilling. During under-balanced drilling hydrocarbon fluid flows into the wellbore, and consequently the drilling equipment at surface has to be designed to handle such inflow. Moreover, special measures must be taken to control the fluid pressure in the wellbore during the drilling process.

US 6,305,469 relates to a method of creating a wellbore in an earth formation, the wellbore including a first wellbore section and a second wellbore section penetrating a hydrocarbon fluid bearing zone of the earth formation, the method comprising drilling the first wellbore section; arranging a remotely controlled drilling device at a selected location in the first wellbore section, from which selected location the second wellbore section is to be drilled; arranging a hydrocarbon fluid production conduit in the first wellbore section in sealing relationship with the wellbore wall, the conduit being provided with fluid flow control means and a fluid inlet in fluid communication with said selected location; operating the drilling device to drill the new wellbore section whereby during drilling of the drilling device through the hydrocarbon fluid bearing zone, flow of hydrocarbon fluid from the second wellbore section into the production conduit is controlled by the fluid flow control means. By drilling through the hydrocarbon fluid bearing zone using the remotely controlled drilling device, and discharging any hydrocarbon fluid flowing into the wellbore through the production conduit, it is achieved that the wellbore pressure no longer needs to be above the formation fluid pressure. The wellbore pressure is controlled by controlling the fluid flow control means. Furthermore, no special measures are necessary for the drilling equipment to handle hydrocarbon fluid production during drilling. In case the second wellbore is to be drilled through one or more layers from which no hydrocarbon fluid flows into the wellbore, it is preferred that the drilling device comprises a pump system having an inlet arranged to allow drill cuttings resulting from the drilling action of the

drilling device to flow into the inlet, and an outlet arranged to discharge said drill cuttings into the wellbore behind the drilling device. Suitably said outlet is arranged a selected distance behind the drilling device and at a location in the wellbore section where a fluid is circulated through the wellbore, which fluid entrains the drill cuttings and transports the drill cuttings to surface. The second wellbore section can be a continuation of the existing wellbore, or can be a side-track or lateral well (i.e. a branch) of the existing wellbore.

It has now been found that a remotely controlled electrically operated drilling device may be passed from the surface to a selected location in a wellbore through a hydrocarbon fluid production conduit and that fluid produced from the formation during the drilling operation may be pumped to the cutting surfaces of the drilling device to cool the cutting surfaces and to transport the drill cuttings away from the drilling device entrained in the pumped fluid.

Thus, the present invention provides a method of drilling a borehole from a selected location in an existing wellbore penetrating a hydrocarbon fluid bearing zone of a subterranean earth formation wherein a hydrocarbon fluid production conduit is arranged in the existing wellbore in sealing relationship with the wellbore wall, the method comprising:

producing fluid from the hydrocarbon fluid bearing zone of the subterranean formation and flowing a first stream of produced fluid directly to the surface through the hydrocarbon fluid production conduit;

passing a remotely controlled electrically operated drilling device from the surface through the hydrocarbon fluid production conduit to the selected location in the wellbore;

operating the drilling device such that cutting surfaces on the drilling device drill the borehole from the selected location in the existing wellbore thereby generating drill cuttings wherein during operation of the drilling device, a second stream of produced fluid is pumped over the cuttings surfaces of the drilling device via a remotely controlled electrically operated downhole pumping means and the drill cuttings are transported away from the drilling device entrained in the second stream of produced fluid.

An advantage of the process of the present invention is that hydrocarbon fluid

may continue to be produced from the existing well during drilling of the borehole. A further advantage of the process of the present invention is the second stream of produced fluid cools the cuttings surfaces of the drilling device in addition to transporting the drill cuttings away from the cutting surfaces.

By produced fluid is meant produced liquid hydrocarbons and/or produced water, preferably produced liquid hydrocarbons. Preferably, the first stream of produced fluid comprises a major portion of the fluid produced from the hydrocarbon fluid bearing zone of the formation.

Preferably, the existing wellbore is provided with a casing and the hydrocarbon fluid production conduit is arranged in the existing wellbore in sealing relationship with the walls of the casing. The casing may be run from the surface to the bottom of the existing wellbore. Alternatively, the casing may be run from the surface into the upper section of the existing wellbore with the lower section of the existing wellbore comprising a barefoot or open-hole completion. Where the existing wellbore has a casing, the borehole formed by the drilling device at the selected location may be a window in the casing. The casing of the existing wellbore at the selected location may be formed from metal in which case the cutting surfaces on the drilling device should be capable of milling a window through the casing by grinding or cutting the metal. Thus, the term "drilling device" as used herein encompasses milling devices. Alternatively, the casing at the selected location in the existing wellbore may be formed from a friable alloy or composite material such that the window may be milled using a drilling device fitted with a conventional drill bit.

The borehole formed by the drilling device may also be a perforation tunnel in the casing and cement of the existing wellbore. Thus, the borehole may be drilled through debris blocking the perforation tunnel. Alternatively, the drilling device may be used to enlarge a perforation tunnel in the existing wellbore.

Preferably, the borehole formed by the drilling device in the existing wellbore comprises a new section of wellbore.

Thus, according to a particularly preferred embodiment of the present invention there is provided a method of drilling a section of wellbore from a selected location in an existing wellbore penetrating a hydrocarbon fluid bearing zone of a subterranean earth formation, wherein a hydrocarbon fluid production conduit is arranged in the

existing wellbore in sealing relationship with the wellbore wall, the method comprising: producing fluid from the hydrocarbon fluid bearing zone of the subterranean formation and flowing a first stream of produced fluid directly to the surface through the hydrocarbon fluid production conduit arranged in the existing wellbore; passing a remotely controlled electrically operated drilling device from the surface through the hydrocarbon fluid production conduit to a selected location in the existing wellbore, from which selected location the section of wellbore is to be drilled; operating the drilling device such that cutting surfaces on the drilling device drill the section of wellbore from the selected location in the existing wellbore thereby generating drill cuttings wherein during operation of the drilling device a second stream of produced fluid is pumped over the cuttings surfaces of the drilling device via a remotely controlled electrically operated downhole pumping means and the drill cuttings are transported away from the drilling device entrained in the second stream of produced fluid.

An advantage of this preferred embodiment of the present invention is that hydrocarbon fluid may continue to be produced from hydrocarbon bearing zone into the existing wellbore during drilling of the new section of wellbore. A further advantage of this preferred embodiment of the present invention is that hydrocarbon fluid may flow from the hydrocarbon fluid bearing zone into the new section of wellbore during the drilling operation.

As discussed above, the first stream of produced fluid comprises a major portion of the fluid produced from the hydrocarbon fluid bearing zone of the formation. Also, as discussed above, the produced fluid may comprise produced liquid hydrocarbons and/or produced water, preferably, produced liquid hydrocarbons.

The section of wellbore which is drilled using this preferred embodiment of the present invention (hereinafter "new wellbore section") may be a continuation of the existing wellbore, or may be a side-track well or a lateral well. By "side-track well" is meant a branch of the existing wellbore where the existing wellbore no longer produces hydrocarbon fluid. By "lateral well" is meant a branch of the existing wellbore where the existing wellbore continues to produce hydrocarbon fluid.

Preferably, the existing wellbore has an inner diameter of 5 to 10 inches. Preferably, the new wellbore section has an inner diameter of 3 to 5 inches. Typically, a

casing is arranged in the existing wellbore as described above.

Suitably, the drilling device is passed from the surface to the selected location in the existing wellbore suspended on a cable. Preferably, the cable is formed from reinforced steel. The cable may be connected to the drilling device by means of a connector, preferably, a releasable connector. Preferably, the cable encases one or more wires for transmitting electricity or electrical signals.

Suitably, the drilling device may be provided with formation evaluation sensors which are electrically connected to recording equipment at the surface via one or more electrical conductor wires in the cable. Preferably, the sensors are located in close proximity to the cutting surfaces on the drilling device.

Preferably, the drilling device is provided with a steering assembly which is used to adjust the trajectory of the new wellbore section as it is being drilled. This steering assembly is electrically connected to equipment at the surface via an electrical conductor wire.

Preferably the cable from which the drilling device is suspended lies within a length of drill tubing which is in fluid communication with a fluid passage in the drilling device. Preferably, the drill tubing extends from the drilling device along a lower section of the cable. It is envisaged that formation evaluation sensors may be located on the drill tubing adjacent the drilling device.

The drill tubing has an outer diameter smaller than the inner diameter of the production tubing thereby allowing the cable and drill tubing to pass through the production tubing. Preferably, the production tubing has an inner diameter of 2.5 to 8 inches, more preferable 3.5 to 6 inches. Preferably the drill tubing has an outer diameter of 2 to 5 inches. Suitably, the length of the drill tubing is at least as long as the desired length of the new wellbore section. Preferably, the drill tubing extends into the lower end of the hydrocarbon fluid production conduit.

The drill tubing may be steel tubing or plastic tubing.

Where the drill tubing is steel tubing, it is envisaged that a housing, preferably a cylindrical housing, may be attached either directly or indirectly to the end of the steel tubing remote to the drilling device, for example, via a releasable connector. Thus, the drilling device is attached to a first end of the steel tubing and the housing to a second end of the steel tubing. For avoidance of doubt, the cable passes through the housing.

An electric motor may be located in the housing and electricity may transmitted to the motor via an electrical conductor wire encased in the cable. The electric motor may be used to rotate the steel tubing and hence the drilling device connected thereto. Preferably, the housing is provided with electrically operated traction means which is used to advance the steel tubing and hence the drilling device through the new wellbore section as it is being drilled. Electricity is transmitted to the traction means via an electrical conductor wire encased in the cable. Suitably, the traction means comprises wheels which engage with and move over the walls of the hydrocarbon fluid production conduit.

As an alternative to rotating the steel tubing, the drilling device may comprise a housing, preferably a cylindrical housing, provided with an electric motor used to rotate a drill bit located at the lower end of the drilling device. Electricity is transmitted to the motor via an electrical conductor wire encased in the cable. The housing of the drilling device may be provided with an electrically operated traction means which is used to advance the drilling device and steel tubing through the new wellbore section as it is being drilled and also to take up the reactive torque generated by the electric motor used to drive the drill bit. Electricity is transmitted to the traction means via an electrical conductor wire encased in the cable. Suitably, the traction means comprises wheels which engage with and move over the wall of the new wellbore section. It is envisaged that the drilling device may be advanced through the new wellbore section using both the traction means provided on the housing attached to the end of the steel drill tubing remote from the drilling device and the tractions means provided on the housing of the drilling device.

Where the drill tubing is formed from steel tubing, the second stream of produced fluid may be pumped to the drilling device through the interior of the steel tubing while the cuttings entrained in the stream of produced fluid (hereinafter "entrained cuttings stream") may be transported away from the drilling device through the annulus formed between the steel tubing and the wall of the new wellbore section. Preferably, the second stream of produced fluid flows from the steel tubing through a passage in the drilling device to the cutting surfaces where the produced fluid cools the cutting surfaces and the cuttings become entrained in the produced fluid. The resulting entrained cuttings stream is then transported away from the cutting surfaces over the

outside of the drilling device and through the annulus formed between the steel tubing and the wall of the new section of wellbore. It is envisaged the produced fluid flowing from the hydrocarbon bearing formation into the annulus may assist in transporting the cuttings through the annulus. The second stream of produced fluid may be pumped to the drilling device through the steel tubing via a remotely controlled electrically operated downhole pumping means located in the cylindrical housing attached to the end of the steel tubing remote from the drilling device. Preferably, the inlet to this downhole pumping means is provided with a filter to prevent any cuttings from being recycled to the drilling device. The second stream of produced fluid may also be drawn to the drilling device via a remotely controlled electrically operated downhole pumping means, for example, a suction pump, located in the housing of the drilling device. The suction pump draws the second stream of produced fluid from the steel tubing through a passage in the drilling device and out over the cuttings surfaces of the drilling device.

Alternatively, the second stream of produced fluid may be drawn to the drilling device through the annulus formed between the steel tubing and the wall of the new section of wellbore and the entrained cuttings stream may be transported away from the drilling device through the interior of the steel tubing. Typically, the second stream of produced fluid is drawn into a first fluid passage in the housing of the drilling device and through a downhole pumping means, for example, a suction pump, located therein. The second stream of produced fluid is then divided into a first divided fluid stream and second divided fluid stream. The first divided fluid stream flows through a second fluid passage in the housing of the drilling device and into the interior of the steel tubing while the second divided fluid stream flows through a third fluid passage in the housing of the drilling device and out over the cutting surfaces where the produced fluid cools the cuttings surfaces and the drill cuttings become entrained in the produced fluid. The resulting entrained cuttings stream is then passed over the outside of the drilling device before being recycled to the first fluid passage in the housing of the drilling device where the entrained cuttings stream is mixed with the second stream of produced fluid. The majority of the cuttings pass into the interior of the steel drill tubing entrained in the first divided fluid stream. The first divided fluid stream containing the entrained cuttings is discharged from the end of the steel tubing remote from the drilling device, preferably into the hydrocarbon fluid production conduit where the cuttings are diluted

into the first stream of produced fluid flowing directly to the surface through the hydrocarbon fluid production conduit. The pressure of the hydrocarbon-bearing zone of the subterranean formation may be sufficiently high that the first stream of produced fluid flows to the surface through the hydrocarbon fluid production conduit by means of natural energy. However, the method of the present invention is also suitable for use in artificially lifted wells. Where the cuttings are transported to the surface with the first stream of produced fluid, the cuttings may be removed from the produced fluid at a hydrocarbon fluid processing plant using conventional cuttings separation techniques, for example, using a hydrocyclone or other means for separating solids from a fluid stream. However, it is also envisaged that the cuttings may disentrain from the first stream of produced fluid may be deposited in the rat hole of the existing wellbore. Parameters affecting disentrainment of the cuttings include the flow rate of the first stream of produced fluid, the viscosity of the produced fluid, the density of the cuttings and their size and shape.

The steel tubing may be provided with expandable casing packers thereby allowing the casing to form a lining for the new wellbore section. When the casing packers are in their non-expanded state, the steel tubing together with the casing packers should be capable of being passed down through the hydrocarbon fluid production conduit to the selected location of the wellbore from which the new wellbore section is to be drilled. Also, the external casing packers should not interfere with the flow of fluid, during the drilling operation, through the annulus formed between the steel tubing and the walls of the new wellbore section. Once the drilling operation is complete, the steel tubing is locked in place in the new wellbore section by expanding the external casing packers. Suitably, the steel tubing extends into the hydrocarbon fluid production conduit. Expandable packers may be provided at or near the bottom of the production conduit to seal the annulus formed between the steel tubing and the hydrocarbon fluid production conduit. The steel tubing is then perforated to allow produced fluid to flow from the hydrocarbon-bearing zone of the formation into the interior of the steel tubing and into the production conduit.

Alternatively, the steel drill tubing may be expandable tubing. When in its non-expanded state, the steel tubing should be capable of being passed down through the hydrocarbon fluid production conduit of the existing wellbore to the selected location in

the existing wellbore from which the new well bore section is to be drilled. Once the drilling operation is complete, the steel tubing may be expanded to form a lining for the new well bore section. Suitably, the steel tubing extends into the hydrocarbon fluid production conduit. The length of the steel tubing which extends into the hydrocarbon fluid production conduit is expanded against the wall of the production conduit thereby eliminating the requirement for an expandable packer. The steel tubing is then perforated to allow produced fluid to flow from the hydrocarbon-bearing zone of the formation into the interior of the expanded steel tubing and into the hydrocarbon fluid production conduit. The steel tubing may be expanded by detaching the drilling device from the cable and steel tubing, pulling the cable to the surface through the hydrocarbon fluid production conduit and attaching a conventional expansion tool thereto, for example, an expandable mandrel. The expansion tool is then inserted into the wellbore through the hydrocarbon fluid production conduit and through the steel tubing. The expansion tool is then drawn back through the steel tubing to expand the tubing. The drilling device may then be retrieved from the wellbore by reattaching the cable to the drilling device and pulling the cable and drilling device from the wellbore through the expanded steel tubing and the hydrocarbon fluid production conduit. Alternatively, an electrically operated rotatable expansion tool may be attached either directly or indirectly to the drilling device at the end thereof opposite the cutting surfaces. The rotatable expansion tool is also releasably attached to the expandable steel tubing, for example, via an electrically operated latch means. Electricity is transmitted to the rotatable expansion tool via an electrical wire encased in the cable. A suitable rotatable expansion tool is as described in US patent application no. 2001/0045284 which is herein incorporated by reference. The rotatable expansion tool is provided with a fluid passage such that, during the drilling operation, the interior of the steel tubing is in fluid communication with a fluid passage in the drilling device. After completion of drilling of the new wellbore section, the rotatable expansion tool is released from the steel tubing. The rotatable expansion tool is then operated to expand the steel tubing by drawing the expansion tool and the associated drilling device through the steel tubing. Following expansion of the steel tubing, the rotatable expansion tool and the associated drilling device may be retrieved from the wellbore through the hydrocarbon fluid production conduit by pulling the cable.

Where the new wellbore section is a lateral well, the portion of the steel drill tubing which passes through the existing wellbore before entering the hydrocarbon fluid production conduit may be provided with a valve comprising a sleeve which is moveable relative to a section of tubing having a plurality of perforations therein. When the valve is in its closed position the sleeve will cover the perforations in the section of steel drill tubing so that produced fluids from the existing wellbore are prevented from entering the hydrocarbon fluid production conduit. When the sliding sleeve is in its open position the plurality of perforations are uncovered and produced fluids from the existing wellbore may pass through the perforations into the steel drill tubing and hence into the hydrocarbon fluid production conduit.

As discussed above, the drill tubing may also be plastic drill tubing. Unlike steel drill tubing, plastic drill tubing is deformable under the conditions encountered downhole. Accordingly, the second stream of produced fluid is drawn to the drilling device through the annulus formed between the plastic drill tubing and the walls of the wellbore and the cuttings stream is transported away from the drilling device through the interior of the drilling tubing. Suitably, the second stream of produced fluid is drawn to the drilling device via a pumping means, for example, a suction pump, located in a housing, preferably a cylindrical housing of the drilling device. The pumping means may be operated as described above. Preferably, the housing of the drilling device is provided with an electric motor used to rotate a drill bit located at the lower end of the drilling device. Preferably, the drilling device is provided with traction means, for example, traction wheels which engage with the walls of the new wellbore section and which are used to advance the drilling device through the new wellbore section as it is being drilled and to take up the reactive torque generated by the electric motor used to drive the drill bit. Preferably, the cuttings stream is passed to the surface through the hydrocarbon fluid production conduit together with the first stream of produced fluid. Alternatively, the cuttings may be deposited in the rat hole of the existing wellbore, as described above.

Suitably, the plastic tubing lies within a sandscreen which extends along the length of the plastic tubing i.e. the sandscreen encases the plastic drill tubing. The sandscreen may be an expandable sandscreen or a conventional sandscreen. The sandscreen may be releasably attached to the cable and/or to the drilling device. Once

the new wellbore section has been drilled, the sandscreen is released from the cable and/or the drilling device, for example, via an electronically releasable latch means. Where the plastic tubing lies within a conventional sandscreen, the drilling device may be detached from the cable and the plastic tubing, for example, via a further electronically releasable latch means thereby allowing the cable and plastic tubing to be pulled from the wellbore through the hydrocarbon fluid production conduit leaving the sandscreen and drilling device in the new wellbore section. Alternatively, the drilling device may be formed from detachable parts wherein the individual parts of the drilling device are sized such that they may be removed from the wellbore through the interior of a conventional sandscreen. Where the sandscreen is an expandable sandscreen, expansion of the sandscreen may allow the drilling device to be retrieved from the wellbore through the expanded sandscreen and the hydrocarbon fluid production conduit. It is envisaged that the sandscreen may be expanded by the steps of:

i. detaching the drilling device from the cable;
ii. pulling the cable and associated plastic drill tubing through the sandscreen and the hydrocarbon fluid production conduit;
iii. attaching a conventional tool for expanding a sandscreen, to the cable, for example an expandable mandrel;
iv. passing the tool through the hydrocarbon fluid production conduit and the sandscreen;
v. drawing the tool back through the sandscreen to expand the sandscreen;
vi. retrieving the tool from the wellbore by pulling the cable through the hydrocarbon fluid production conduit;
vii. retrieving the drilling device from the new section of wellbore by reinserting the cable, reattaching the drilling device to the cable and pulling the cable and attached drilling device through the expanded sandscreen and through the production tubing.

Alternatively, an electrically operated rotatable expansion tool may be attached either directly or indirectly to the drilling device at the end thereof opposite the cutting surfaces. The rotatable expansion tool may also be releasably attached to the expandable sandscreen, for example, via an electrically operated latch means. Electricity is transmitted to the rotatable expansion tool via an electrical wire encased in the cable. As discussed above, a suitable rotatable expansion tool is as described in US patent application no. 2001/0045284. The rotatable expansion tool is provided with a fluid

passage such that, during the drilling operation, the interior of the plastic tubing is in fluid communication with a fluid passage in the drilling device. After completion of drilling of the new wellbore section, the rotatable expansion tool may be released from the sandscreen. The rotatable expansion tool is then operated to expand the sandscreen by drawing the expansion tool and the associated drilling device through the sandscreen. Following expansion of the sandscreen, the plastic drill tubing, the rotatable expansion tool and the associated drilling device may be retrieved from the wellbore through the hydrocarbon fluid production conduit by pulling the cable.

It is also envisaged that where the plastic drill tubing is formed from an elastic material, the plastic drill tubing may be temporarily sealed at its end remote from the drilling device. Produced fluid flowing into the new section of wellbore in the vicinity of the drilling device is then pumped into the interior of the plastic tubing via the pumping means located in the housing of the drilling device. The tubing is thereby expanded radially outwards owing to the pressure of fluid building up in the temporarily sealed interior of the tubing. Thus, the plastic drill tubing will expand the sandscreen against the walls of the new wellbore section. Once the sandscreen has been expanded, the fluid pressure in the plastic drill tubing may be relieved by unsealing the end of the plastic drill tubing remote from the drilling device. The plastic drill tubing will then contract radially inwards. The drilling device may then be removed from the wellbore by pulling the cable and associated plastic drill tubing through the expanded sandscreen and the hydrocarbon fluid production conduit.

Where produced fluid flows from the hydrocarbon bearing zone of the formation into the new wellbore section there may be no requirement for any drill tubing. Thus, the drilling device may comprise a housing provided with a motor to drive a drill bit located on the lower end of the drilling device. An electrically operated pumping means, for example, a suction pump, may also be located in the housing of the drilling device. The drilling device, suspended on a cable, may then be passed to the selected location in the existing wellbore from which the new wellbore section is to be drilled. As the new wellbore section is being drilled, the pumping means located in the housing of the drilling device may draw produced fluid flowing from the hydrocarbon fluid bearing zone of the reservoir into the new wellbore section through a passage in the drilling device and out over the cuttings surfaces of the drilling device. The resulting

entrained cuttings stream then flows around the outside of the drilling device and passes through the new well bore section together with the produced fluid flowing from the formation into the new well bore section.

Where the new wellbore section is a side-track or multi-lateral well and the existing wellbore is provided with a casing which runs down through the selected located where the new wellbore section is to be drilled, it is necessary to mill a window through the casing before commencing drilling of the new wellbore section. Where the casing is formed from metal, this may be achieved by lowering a whipstock and a first drilling device having hard cuttings surfaces suitable for milling through metal by grinding and cutting, suspended on a reinforced steel cable, through the hydrocarbon fluid production conduit. Suitably, the first drilling device is provided with traction means. Once the whipstock has emerged from the bottom of the hydrocarbon fluid production conduit and is located in the region of the cased wellbore where it is desired to drill the side-track or lateral well, the whipstock is locked into place in the casing, for example, via extendible arms. By whipstock is meant a device having a plane surface inclined at an angle relative to the longitudinal axis of the wellbore which causes the first drilling device to deflect from the original trajectory of the wellbore at a slight angle so that the drilling device engages with and mills a window through the metal casing of the wellbore. Once a window has been milled through the metal casing, the first drilling device may be removed from the wellbore by pulling the cable out of the wellbore. A second drilling device comprising a conventional drill bit is then attached to the cable which is then reinserted into the wellbore through the hydrocarbon fluid production conduit. Preferably, the cable passes through a length of drill tubing which is in fluid communication with a fluid passage in the drilling device, as described above. The whipstock then causes the second drilling device to deflect into the window in the casing such that operation of the drilling device results in the drilling of a side-track or lateral well through the hydrocarbon-bearing zone of the formation. However, it is also envisaged that the casing at the selected location of the wellbore may be formed from a friable alloy or composite material such that a window may be formed in the casing using a drilling device comprising a conventional drill bit.

Where a whipstock is employed to deflect the drilling device(s), the whipstock may remain in the existing wellbore following completion of drilling of the new

wellbore section. Preferably, the whipstock is provided with a fluid by-pass to allow produced fluid from the existing wellbore to continue to flow to the surface through the hydrocarbon fluid production conduit. Preferably, the whipstock is retrievable through the production tubing. Preferably, the whipstock is collapsible, for example, has retractable parts and is capable of being retrieved through the hydrocarbon fluid production conduit when in its collapsed state, for example, by attached a cable thereto and pulling the cable from the wellbore through the hydrocarbon fluid production conduit.

In yet a further embodiment of the present invention there is provided a method of removing debris from a perforation tunnel formed in the casing and cement of a cased wellbore or of enlarging such a perforation tunnel using a remotely controlled electrically operated micro-drilling device. The micro-drilling device comprises an electrically operated motor for driving a drill bit, an electrically operated pumping means and an electrically or hydraulically operated thruster means. Suitably, the motor for driving the drill bit but has a maximum power of 1 kw. The drill bit is sized to form boreholes having a diameter in the range 0.2 to 3 inches, preferably, 0.25 to 1 inches. The micro-drilling device is suspended on a cable via a connector and is passed from the surface through the hydrocarbon fluid production conduit to a selected location is the existing wellbore containing the perforation tunnel from which debris is to be removed or which is to be enlarged. The micro-drilling device is orientated adjacent the perforation with the drill bit aligned with the perforation tunnel, for example, by using a stepper motor located at the upper end of the drilling device. The stepper motor allows the micro-drilling device to rotate about its longitudinal axis while the connector and cable remain stationary. The micro-drilling device may be locked in place in the cased wellbore via hydraulic rams which, when expanded, engage with the walls of the wellbore. During the drilling operation, a produced fluid stream is pumped through a first passage in the micro-drilling device and out over the cutting surfaces of the drill bit via the pumping means. An entrained cuttings stream is transported away from the cutting surfaces, for example through a second passage in the micro-drilling device. The thruster means provides a thrusting force to the drill bit such that the drill bit moves through the perforation tunnel. An advantage of this further embodiment of the present invention is that any produced fluids flowing from the formation through the perforation

tunnel into the wellbore will assist in transporting the drill cuttings out of the perforation tunnel. The micro-drilling device may additionally comprise a mill mounted on a thruster means, for example, a hydraulic ram. The mill may be rotated by means of a further electrically operated motor while the thruster means provides a force to the mill so that a perforation is milled through the casing. Suitably the electrically operated motor for the mill has a maximum power of 0.5 kw. Suitably the casing mill is sized such that the perforation in the casing has a diameter of 1 to 2 inches. The drill bit may then be positioned in the perforation to form a perforation tunnel. A preferred micro-drilling device is illustrated below.

Referring to Figure 1, an existing wellbore 1 penetrates through an upper zone 2 of the subterranean formation and into a hydrocarbon-bearing zone 3 of the subterranean formation located below the upper zone 2. A metal casing 4 is arranged in the existing wellbore 1 and is fixed to the wellbore wall by a layer of cement 5. A hydrocarbon fluid production conduit 6 is positioned within the existing wellbore 1 and a packer 7 is provided at the lower end to the casing 4 to seal the annular space formed between the conduit 6 and the casing 4. A wellhead 8 at the surface provides fluid communication between the conduit 6 and a hydrocarbon fluid production facility (not shown) via a pipe 9. An expandable whipstock 10 is passed through the conduit 6 and is locked in place in the existing wellbore 1 via locking means 11. A remotely controlled electrically operated drilling device 12 is passed into the existing wellbore through the hydrocarbon fluid production conduit 6 suspended on a reinforced steel cable 13 comprising at least one electric conductor wire (not shown). The lower end of the reinforced steel cable 13 passes through a length of steel drill tubing 14 which is in fluid communication with a fluid passage (not shown) in the drilling device 12. The drilling device 12 is provided with an electrically operated motor (not shown) arranged to drive a drill bit 15 located at the lower end of the drilling device 12. A cylindrical housing 16 provided with a pump (not shown) is attached to the upper end of the steel drill tubing 14. The drilling device 12 and/or the housing 16 are provided with traction wheels 17 which are used to advance the drilling device 12 through a new wellbore section 18.

The new wellbore section 18 is drilled using the drilling device 12 in the manner described hereinafter, the new wellbore section extending from a window 19 in the

casing 4 of the existing wellbore 1 into the hydrocarbon-bearing zone 3 and being a side-track well or lateral well. The window may have been formed using a drilling device comprising a mill which is passed through the production conduit 6 suspended on a cable and is then pulled from the existing wellbore. During drilling of the new wellbore section 18, produced fluid is pumped down the interior of the steel drill tubing 14 to the drilling device 12 via the pump located in the cylindrical housing 16. The produced fluid flows from the steel drill tubing 14 through the fluid passage in the drilling device to the drill bit 15 where the produced fluid serves both to cool the drill bit 15 and to entrain drill cuttings. The drill cuttings entrained in the produced fluid is then passed around the outside of the drilling device 12 into the annulus 20 formed between the steel drill tubing 14 and the walls of the new wellbore section 18.

A plurality of formation evaluation sensors (not shown) may be located either on the drilling device 12 in close proximity to the drill bit 15 or on the end of the steel drill tubing 14 which is connected to the drilling device 12. The formation evaluation sensors are electrically connected to recording equipment (not shown) at the surface via electric conductors which extend along the length of the cable 13. As drilling with the drilling device 12 proceeds, the formation evaluation sensors are operated to measure selected formation characteristics and to transmit signals representing the characteristics via the electric conductors of the cable 13 to recording equipment at the surface (not shown).

An inertial navigation system (INS, not shown) is included in the drilling device 12 for sampling data to assist navigation of the drilling device 12 through the new wellbore section 18.

After drilling of the new wellbore section 18, the steel drill tubing 14 may be expanded and the drilling device 12 can be retrieved by pulling the cable from the wellbore through the expanded steel drill tubing and the hydrocarbon fluid production conduit 6.

Referring to Figure 2, an existing wellbore 30 penetrates through an upper zone 31 of the subterranean formation into a hydrocarbon-bearing zone 32 of the subterranean formation located below the upper zone 31. A metal casing 33 is arranged existing wellbore 30 and is fixed to the wellbore wall by a layer of cement 34. A hydrocarbon fluid production conduit 35 is positioned within the existing wellbore 30

and is provided at its lower end with a packer 36 which seals the annular space between the conduit 35 and the casing 33. A wellhead 37 at the surface provides fluid communication between the hydrocarbon fluid production conduit 35 and a hydrocarbon fluid production facility (not shown) via a pipe 38. An expandable whipstock 39 is passed down the conduit 6 and is locked in place in the existing wellbore via locking means 40. A remotely controlled electrically operated drilling device 41 is passed into the existing wellbore through the hydrocarbon fluid production conduit suspended on a reinforced steel cable 42 comprising at least one electric conductor wire (not shown). The lower end of the reinforced steel cable 42 passes through a length of plastic drill tubing 43 which is in fluid communication with a fluid passage (not shown) in the drilling device 41. The plastic drill tubing 43 passes through an expandable sandscreen 44 which is releasably connected to the drilling device 41. The drilling device 41 is provided with an electrically operated pumping means and an electrically operated motor (not shown) arranged to drive a drill bit 45 located at the lower end of the drilling device 41. The drilling device 41 is also provided with traction wheels 46 for advancing the drilling device 41 though a new wellbore section 47 as it is being drilled.

A new wellbore section 47 is drilled using the drilling device 41 in the manner described hereinafter, the new wellbore section extending from a window 48 in the casing 34 of the existing wellbore 30 into the hydrocarbon-bearing zone 32 and being a side-track well or lateral well. The window may be formed using a drilling device comprising a mill which is passed through the production conduit suspended on a cable and which is then retrieved from the existing well bore by pulling the cable. During drilling of the new wellbore section 47, produced fluid is drawn down the annulus formed between the sandscreen 44 and the walls of the new wellbore section to the drilling device 41 and the cuttings entrained in the produced fluid are transported away from the drilling device 41 through the interior of the plastic drill tubing 43.

As discussed above, a plurality of formation evaluation sensors (not shown) may be located either on the drilling device 41 in proximity to the drill bit 45 or on the end of the plastic drill tubing 43 which is connected to the drilling device 41.

Also, as discussed above, an inertial navigation system (INS, not shown) may be included in the drilling device 41 for sampling data to assist navigation of the drilling

device 41 through the new wellbore section 47.

After drilling of the new wellbore section 47, the sandscreen 44 may be expanded and the drilling device 41 may be retrieved by pulling the cable 42 and plastic drill tubing 43 from the wellbore through the expanded sandscreen 44 and the hydrocarbon fluid production conduit 35.

Figure 3 illustrates a remotely controlled electrically operated micro-drilling device 1 according to a preferred aspect of the present invention. The remotely controlled electrically operated micro-drilling device 1 is passed into an existing cased wellbore 2 through a hydrocarbon fluid production conduit (not shown) suspended on a cable 3 via a connector 4. The cable 3 comprises at least one electrical conductor wire (not shown). The micro-drilling device 1 is provided with a mill 5 mounted on a hydraulic piston 6 and a drill bit 7 located at the end of a flexible rotatable drive tube 8. A pump 9 is in fluid communication with the produced fluids in the wellbore via an inlet 10 and with the interior of the flexible rotatable drive tube 8. The drive tube 8 is arranged within a telescopic support tube 11 such that an annular space is formed between the drive tube and the support tube. The concentrically arranged drive tube 8 and support tube 11 pass through a guide tube 12 thereby orientating the drill bit 7.

During operation of the micro-drilling device, a stepper motor 13 is used to rotate the micro-drilling device 1, about its longitudinal axis, relative to the connector 4. Once the micro-drilling device 1 has been orientated in the wellbore, it is locked in place against the casing of the wellbore via hydraulic rams 14. The mill is then rotated via a first electric drive 15 while hydraulic piston 6 provides a thrust force to the mill 5 so that a perforation is milled through the casing. After the milling operation has been completed, the drill bit 7 is aligned with the perforation and the drilling device is locked in place in the wellbore using the hydraulic rams 14. The drive tube 8 and hence the drill bit 7 is then rotated by means of a second electric drive 16. During the drilling operation, produced fluid is drawn from the wellbore through the inlet 10, via the pump 9, and is passed through the interior of the drive tube 8 to the drill bit 7 while cuttings entrained in the produced fluid are carried away from the drill bit 7 via the annulus formed between the drive tube 8 and the telescopic support tube 11. A thrust force is provided to the drill bit 7 through actuation of further hydraulic rams 17 which drive telescopic sections of the support tube 11 together such that at least one section of the

support tube slides into another section of the support tube.

Fig. 1

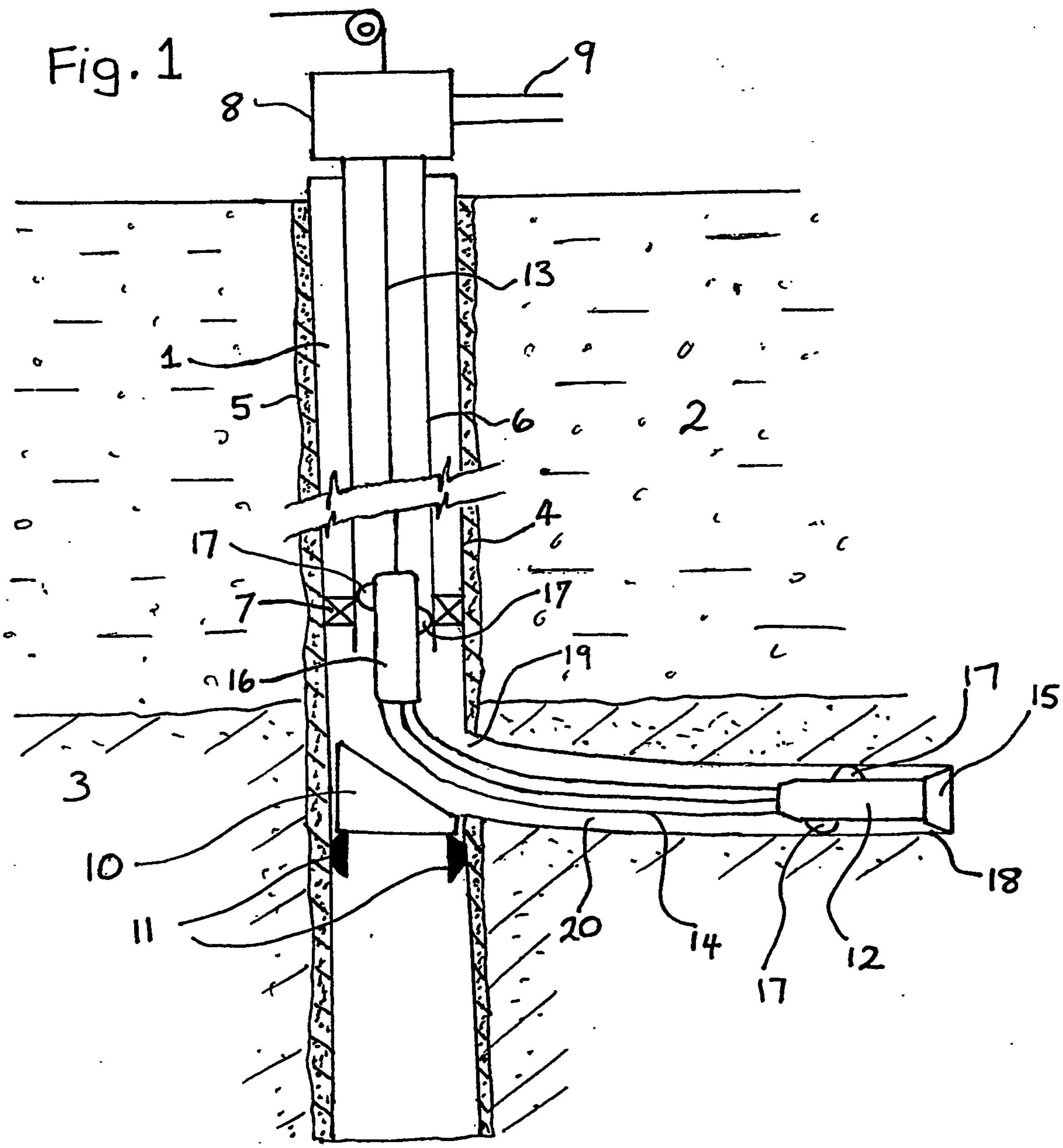
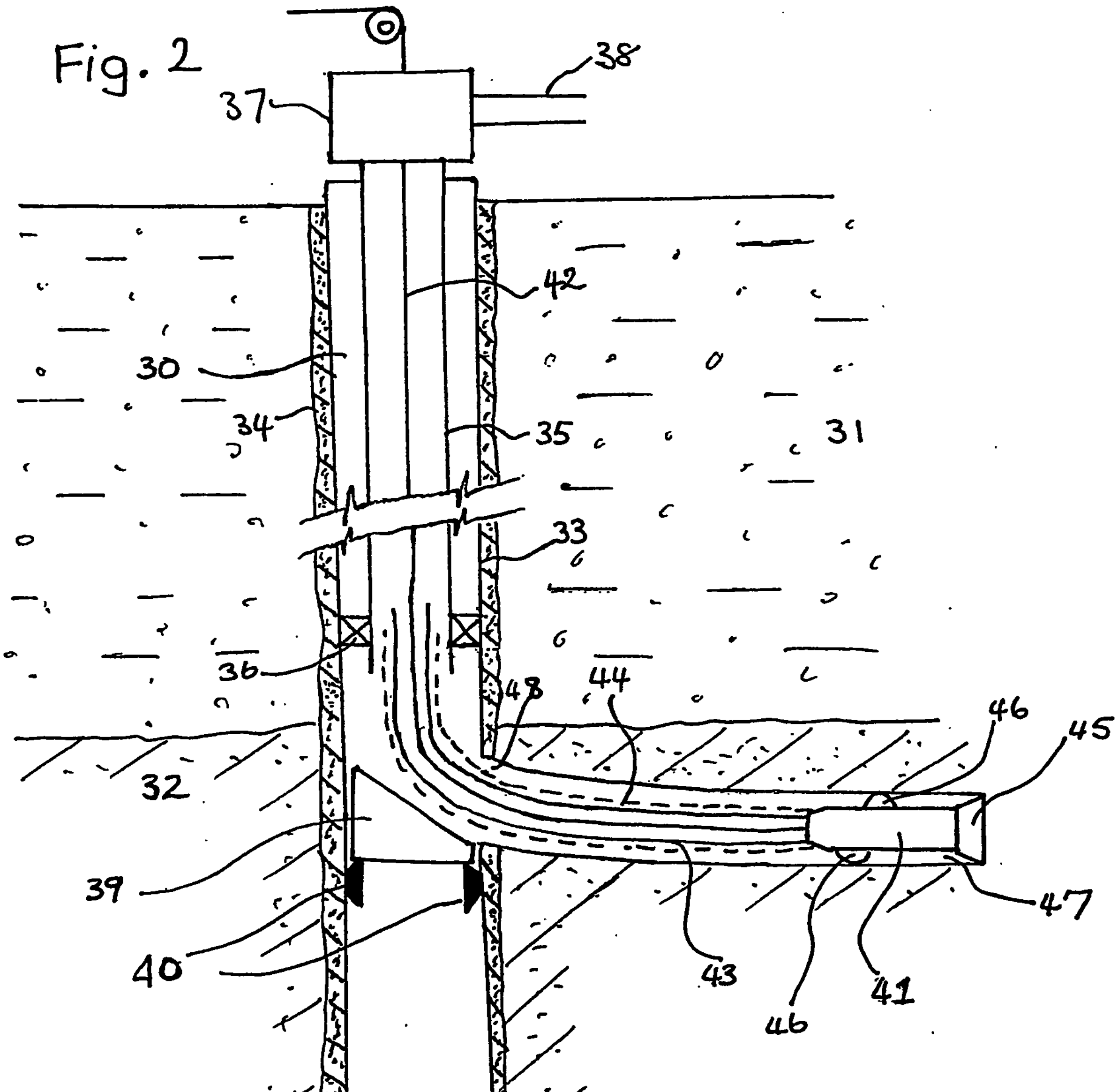


Fig. 2



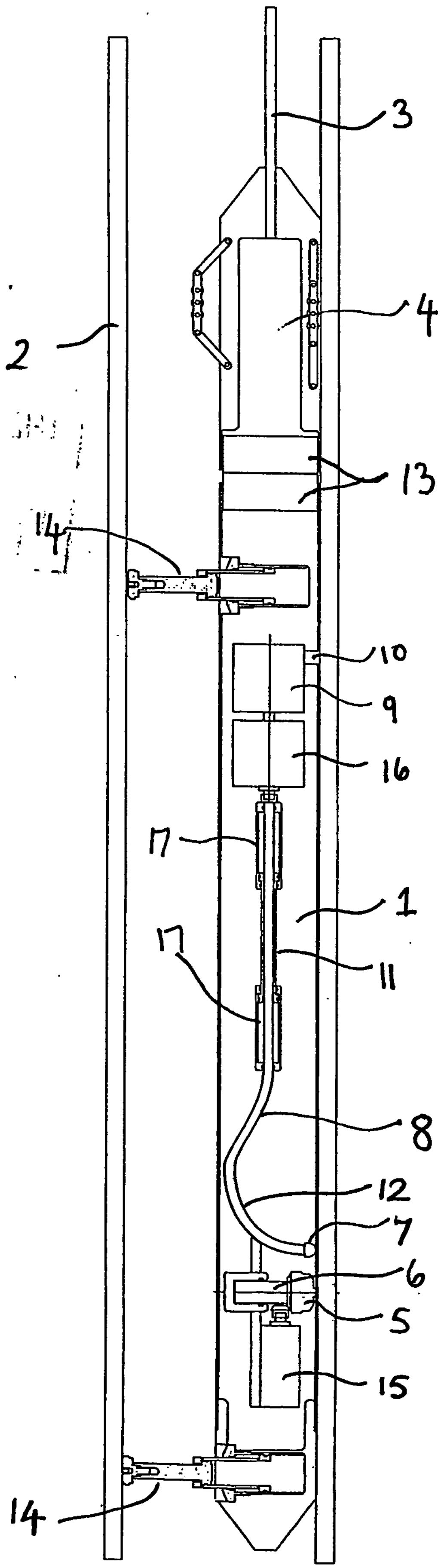


FIGURE 3